It produces swollen galls along the stems and small twigs and occasionally at the base of the canes near the ground. The galls are irregular and of various sizes. Often the gall involves the entire circumference of the branch and affected branches and twigs die. In Washington certain varieties and selections are badly infected, while plants of a different selection in adjacent rows may be healthy. Although various other host plants become infected when inoculated by bacteria isolated from blueberry galls, the blueberry strain of the crown gall organism appears to be best adapted to the blueberry. The disease is probably spread in the field or nursery when plants are pruned or when softwood cuttings are made. No attempts have been made to control the disease in blueberry fields.

Tip blights of blueberries occasionally are common. They are probably caused by winter injury, excessive soil moisture, or other environmental factors that weaken the bush. Frequently stem tips of bushes, weakened by other causes, are infected by weakly parasitic fungi. *Diaporthe (Phomopsis) vaccinii* is reported to be a cause of tip blight in North Carolina, New Jersey, and New England. That fungus is not often encountered, however, and is only one of a number of fungi that may be found in blighted tips. In Washington *Diaporthe vaccinii* occurs as a saprophyte on dead blueberry tips.

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Disorders of Cranberries

Herbert F. Bergman

Fruit rots cause an annual loss of 10 to 15 percent in our crop of cranberries, which are grown extensively in Massachusetts, Wisconsin, and New Jersey and less widely in Washington, Oregon, Maine, and Rhode Island. The value of the crop is 10 million to 20 million dollars a year.

Two or three decades ago the losses went as high as 25 percent, but they have been reduced by changes in cultural practices, improvements in fungicides, greater efficiency in handling and storing, and the development of the canning industry, which offers an immediate and profitable outlet for the berries that—although sound at harvest—probably would develop excessive decay if they were stored and shipped as fresh fruit.

Directly affecting the abundance of rot are the amount and frequency of rain and the temperature and humidity. Humidity and temperature (to a lesser extent) are affected by local conditions. A local condition that bears on humidity is the density of vine growth. Excessive growth prevents the evaporation of water among and under the vines after rain, fog, or dew. Thus the atmosphere may remain saturated or nearly saturated for hours after the air and soil surface under the thinner vines have dried. Poor drainage also keeps the soil wet and makes a high humidity under the vines.

The application of nitrogenous fertilizers, late holding of the winter flood (particularly holding until July or holding late in successive years), sanding too frequently, or too heavy applications of sand on bogs with dense vine growth promote excessive growth especially on bogs with peat or muck bottom. Excessive use of water (such as too frequent flooding and holding water high in the ditches) also tends to increase the amount of rot because the surface of the soil is kept wet and the humidity of the air under the vines is increased.

To find out the relationship between weather in Massachusetts and the ability of cranberries to remain in good condition, extensive studies were made by Dr. Neil E. Stevens, formerly of the Department of Agriculture. He began the work with Dr. C. L. Shear in 1915. Although he worked on all phases of investigation pertaining to cranberries, his chief interests were weather in relation to keeping quality, the occurrence and spread of the false blossom disease, and the effect of acidity or alkalinity of flooding water on the productivity of cranberry vines. Dr. Shear, also of the Department of Agriculture, went to New Jersey in 1901, at the request of the American Cranberry Growers' Association, and began studies which were continued until 1907. He made extensive observations in the field, collected specimens in New Jersey and Massachusetts, and made laboratory studies of the various diseases of cranberries. He also conducted experiments in New Jersey on methods of controlling fruit rot. As a result of the work, most of the present knowledge as to the identity and life histories of the fungi causing fruit rot as well as of those causing diseases of the vines was obtained.

Records over a long period show that the keeping quality of berries from individual bogs and from an entire region varies greatly from year to year.

An apparent correlation was found in Massachusetts and New Jersey between exceptionally large crops and unusually poor keeping quality. Keeping quality was correlated with rainfall, but the correlation between keeping quality and the number of rainy days in July and August, when the fruit is developing, was closer than the correlation between keeping quality and total amount of rain. The amount of rain in September has no bearing on keeping quality.

The correlation between keeping quality and temperatures during May and June was very close. The basis used in comparing temperatures in different years was the total of "day degrees" above 50° F. Fifty was subtracted from the mean temperature of each day and the remainders were added together. Fifty was chosen as a base point because many fungi begin active growth on cranberries at about that temperature.

During the years of the study, an unusual amount of rot occurred in berries of the Early Black variety whenever the May and June temperatures were unusually high. Moreover, those were the only years in which an unusual amount of decay is known to have occurred in Early Black. In years in which May and June temperatures were lower than normal, the keeping quality of Early Black was better.

Early Black and Howes, the oldest of the cultivated varieties, are the principal ones grown in Massachusetts, where about 65 percent of the entire crop of the United States is produced. McFarlin is grown to a limited extent. Early Black and Howes are grown extensively in New Jersey. The principal variety in Wisconsin is Searles, and McFarlin is next in importance. McFarlin is the most important variety in Washington and Oregon, but Searles also is grown to a considerable extent.

The keeping quality of berries of the Howes variety also was poor in all years in which that of Early Black was poor. The keeping quality of Howes, however, is less definitely correlated with temperature during the growing season than that of Early Black.

Field observations indicate that in determining the keeping quality of the general crop, temperatures during May and June are the most important; distribution of rainfall and temperatures during July and August come next; and the size of the crop, third.

The keeping quality of cranberry crops in Massachusetts and New Jersey vary to some extent independently of each other, although it has been observed that when the keeping quality of the crop in either State has been conspicuously poor that of the crop in the other State also has been below normal.

The keeping quality of the cranberry crops of Wisconsin and of the Washington-Oregon areas also varies from year to year, depending on weather conditions during the growing season. In the Washington-Oregon areas rainy weather during the picking season is apparently the most important factor in determining the amount of rot that will occur.

EIGHT SPECIES of fungi are known to be important causes of fruit rot: *Guignardia vaccinii*, *Acanthorhyncus vaccinii*, *Glomerella vaccinii*, *Godronia cassandrae*, *Diaporthe vaccinii*, *Sporonema oxycocci*, *Pestalotia vaccinii*, and *Ceuthospora lunata*.

The rots caused by most of them are practically the same in external appearance. The fungi causing them can be identified only by making cultures from the rotten berries and identifying the fungi in the cultures.

The fungi grow, in culture, at widely varying rates at different temperatures. *Godronia* and *Sporonema* grow slightly at 32° F., and grow most rapidly at about 59° and 68°, respectively. *Diaporthe*, *Glomerella*, and *Guignardia* begin to grow between 35° and 40°, and their rate of growth increases rapidly above 50°. They grow well at temperatures between 59° and 86° and make their best growth at 82°, 77°, and 77°, respectively. *Acanthorhyncus*, however, begins to grow only at temperatures of 60° to 70° and makes its best growth at about 85°.

Because temperatures in New Jersey during the growing season are higher than in other cranberry-growing regions, field rot occurs on the bogs more abundantly there and often has caused the loss of 50 to 75 percent of the crop in unsprayed bogs. Many bogs in New Jersey, however, produce berries of good keeping quality; most of the rot there is due to fungi that grow best at high temperatures. *Guignardia* is the most important; *Acanthorhyncus* is next; a small part is caused by *Glomerella*.

Temperatures during the growing season in Massachusetts usually are high enough to permit the development of field rot. It usually occurs, however, only on a few bogs, but on them sometimes causes the loss of 15 to 40 percent of the crop. In years when conditions are more favorable for rot, it is found on a greater number of bogs and becomes more serious on the few bogs where it occurs yearly.

When field rot occurs, *Glomerella* generally is the principal cause, particularly in early varieties. Some seasons, however, the temperatures may be higher or lower than normal, and are higher on some bogs than on others. In years in which temperatures during the growing season are above normal, and because of differences in local conditions on some bogs, or parts of them, *Guignardia*, *Sporonema*, and *Diaporthe* are sometimes more important as causes of rot than *Glomerella*. *Acanthorhyncus* very rarely occurs on Massachusetts bogs.

Field rot is negligible in Wisconsin. It occurs only occasionally in Washington and Oregon. Most of the rot there is caused by *Godronia* and occurs during storage. In Wisconsin, *Godronia* is the only fungus that causes more than a negligible amount of rot, but in Washington and Oregon a considerable part of it is caused by *Ceuthospora*. Occasionally serious loss due to field rot caused by the cottonball fungus, *Sclerotinia oxycocci*, occurs.

The crucial period seems to be near and during flowering, when the fungi causing fruit rot gain entrance into the berries. The fungi apparently are always present on bogs although not always in sufficient numbers to cause a noticeable amount of rot.

Mature fruiting bodies, ready to discharge spores, often are found on old leaves, stems, and dried berries on bogs in Massachusetts within 2 weeks after the winter flood has been drawn off and are abundantly present in May and June. The fruiting bodies discharge spores during and after rain and periods of fog and when the vines are wet with dew. Wind and water may carry the spores to blossoms and leaves. Whenever enough moisture is present, the spores germinate; germ tubes from them grow into the ovaries of flowers and cause rot later.

Spores may also be carried to the leaves where they germinate, the germ tubes entering the leaves, where the fungus continues to grow and later forms fruiting bodies on the surface. Spores are discharged from the fruiting bodies before and during the flowering period of the following year to initiate infection for that season.

THE USE OF FUNGICIDES greatly reduces the amount of rot before and after harvest. Spraying is most necessary in New Jersey and has been generally practiced there since the early 1900's. Spraying has been necessary on only comparatively few bogs in Massachusetts. Spraying generally is not necessary in Wisconsin. In Washington and Oregon, the weather during harvest has a much greater influence on the amount of rot than spraying does.

Most generally used in New Jersey until 1945 was bordeaux mixture 8–8–100, with 2 pounds of rosin fish-oil soap added. Four or five applications of the spray were made. A 10–4–100 bordeaux, with 1 pound of rosin fish-oil soap, has been used in Massachusetts. Only two applications are necessary, one at the beginning of the blossoming period and the second near the end.

Since 1945 an organic fungicide, ferbam (ferric dimethyl dithiocarbamate), has been used extensively in New Jersey and to a considerable extent in Massachusetts. It has largely replaced bordeaux.

Berries picked when they are dry keep better than those picked wet. The practice of water raking, which is extensive in Wisconsin, often increases the amount of rot that develops after harvest. The amount of rot in water-raked berries that remain wet for some time after they are picked is decidedly greater than in those dried promptly, and the amount of rot in the latter is greater than in those picked dry. That is true also in Washington and Oregon, where, in years when autumn rains begin before the berries are harvested, the berries have to be picked wet.

Bruising, even when relatively slight, causes a great amount of rot in berries during storage and marketing. Bruising occurs when the berries are picked, screened, and packed. Much of it can be avoided by care in harvesting and later handling.

Berries in storage must be kept at a low temperature and be well ventilated to reduce loss by rot. During the early part of the picking season in New Jersey and in Massachusetts, the berries often are warm when picked. They should be cooled as quickly as possible in storage. Berries keep best when stored at about 35° F. Extensive sterile breakdown occurs in berries stored at 30° to 32°.

Storage tests with cranberries in an atmosphere containing up to 10 percent carbon dioxide showed that an increase in the carbon dioxide content was injurious rather than beneficial. In an atmosphere with a carbon dioxide content even as low as 2.5 percent, the loss was greater than in normal ventilated storage.

Fungus diseases of leaves and stems often are conspicuous and sometimes locally serious, but they have never been known to be of great commercial importance. The disease known as rose bloom causes the buds in the axils of the old leaves to grow out as abnormal lateral shoots bearing greatly enlarged, rose-colored leaves. The disease was most abundant in Massachusetts and was found to some extent almost every year before 1945, but since then there have been no serious outbreaks, possibly because of changes in cultural practices. Rose bloom is occasionally abundant in Washington and Oregon.

A disease known as fairy ring caused by a fungus of the mushroom type occurs frequently in Massachusetts and New Jersey. The fungus makes a dense underground growth that kills the vines in a zone 3 to 4 feet wide where the fungus is active. After the fungus has killed the vines over an area 8 to 10 feet in diameter, the middle again becomes covered with healthy vines thus forming a ring.

Another disease that causes a rot, known as hard rot, and causes a tip blight of vines occurs frequently in Wisconsin, and is sometimes locally serious in Washington and Oregon. It also occurs occasionally in Massachusetts but is much less important there than in the other areas.

FALSE BLOSSOM was prevalent on three varieties in Wisconsin by 1906. The disease was first found in Massachusetts in 1914 and in New Jersey in 1915, and was general in those States by 1924. Apparently the disease was carried there in infected vines from Wisconsin.

The disease gets its name from the abnormal character of the flowers, which, instead of hanging downward, become erect and have enlarged, greenish, and somewhat leaflike calyx lobes. The petals are shorter, broader, and reddish or greenish. The stamens and pistils are more or less malformed. No fruit is produced.

By 1928 false blossom threatened to wipe out the cranberry industry in Wisconsin, Massachusetts, and New Jersey. It caused a reduction in the crop in Wisconsin and a downward trend in production in New Jersey, which began about 1924 and was strikingly evident by 1932. Many bogs in Massachusetts also were seriously affected.

Irene Dobrosky, a research worker in New Jersey, proved in 1927 that false blossom is caused by a virus carried by the blunt-nosed leafhopper. Earlier investigators had believed it was due to a disturbance in nutrition.

Dr. L. O. Kunkel, of the Boyce Thompson Institute, had suggested in 1924 that leafhoppers might be the carriers. A survey in 1925 and 1926 had shown that only one genus of leafhopper occurred in the regions in which false blossom was abundant and that it was not present in Washington and Oregon, where false blossom was found not to spread.

No cultivated varieties of cranberries are free from false blossom, but they vary in susceptibility. Howes is very susceptible. Shaw's Success, a variety not commonly grown, is the most resistant. Early Black and McFarlin are intermediate. The resistance is not an actual resistance that is due to opposition offered by the plant to infection by the disease. It is due, rather, to a difference in the preference of leafhoppers to feed on the different varieties.

The Department of Agriculture began a breeding program in 1929 to develop good, resistant varieties. Crosses in which one or both parents were known to be somewhat resistant to false blossom were made in Wisconsin and Massachusetts. From the crosses 10,685 seedlings have been grown. From a cross made at the New Jersey Agricultural Experiment Station 112 other seedlings have been grown. Forty of the more promising seedlings, including six from the New Jersey crosses, were selected in 1940. In addition 182 other selections were made in 1945, making a total of 222 seedlings selected for a second test.

A selective feeding test—a "cafeteria test" for leafhoppers—to ascertain susceptibility to false blossom was made in 1945 on 362 seedlings selected in

1944. In the test leafhoppers that spread the disease were allowed a choice of different varieties on which to feed. Since the attractiveness of different varieties to leafhoppers seemed to be correlated with the rate of spread of the disease on those varieties in the field, the method was valuable in evaluating the probable resistance of the seedlings. Seedlings with the poorest ratings in the test were discarded, and 93 were included among the 182 selected in 1945 for a second test.

The 40 selections made in 1940 were planted in rod-square plots in New Jersey in 1941. Selections were made from them in 1945 and again in 1949. From the latter, three were named—Beckwith, Stevens, and Wilcox. Plans for their distribution to growers in Massachusetts, New Jersey, and Wisconsin have been made so they can be tested on a large scale.

Further tests of the 40 selections of 1940, the 93 selections of 1945, and some others were started in Massachusetts, New Jersey, and Wisconsin, in the hope that new, healthier, and better varieties can be developed.

A PHYSIOLOGICAL DISEASE is one that injures or kills any part of a plant, without involving a fungus or other parasitic organism, or any disturbance of the normal growth or behavior of a plant. Such injury to flower buds and growing tips of cranberry vines, often severe enough to cause their death, was observed in 1919 as a result of flooding bogs in June to control insects. The most serious injury of this kind to cranberries is caused by winter flooding.

Cranberry bogs usually are flooded in winter as a protection against winterkilling. The practice often hurts crop production. When submerged for a long time, cranberry vines may be so injured that their yield the following summer is reduced or destroyed.

The possibility that the injury might be due to a lack of oxygen in the flooding water was suggested by the fact that its lack caused injury to buds, flowers, and growing tips of vines in June flooding. Winter-flooding water often contains little or no oxygen. Injury occurs only on bogs on which the oxygen content of the water was very low at some time during the winter.

Investigations in Massachusetts proved that forms of injury not previously recognized as such are caused by a lack of oxygen during the winter. Observations in New Jersey showed that serious injury from winter flooding occurs there also.

Injury resulting from a lack of oxygen in the water during the winter-flooding period varies greatly in severity. In the most extreme cases it causes the death of some of the stems, leaves, and buds. Other forms of injury are loss of leaves of the preceding season (leaf drop), death of the terminal (fruit) buds, death of small areas of leaf tissue in embryonic leaves within the terminal bud, retardation in the development of the new growth of the uprights from the terminal buds, death of some or all the flower buds, failure of the flowers to set fruit, failure of the fruits to grow to mature size, and reduction in the size of mature fruits.

The occurrence and degree of injury are determined primarily by the relation between the amount of dissolved oxygen in the water and the amount of oxygen required by the cranberry vines.

Water in contact with the air normally contains oxygen in solution. The greatest amount of oxygen that water can hold in solution at 32° F. is about 14 parts per million, at 40° about 12.4, and at 50° about 11.

The oxygen content of the water of the flooded bog tends to remain uniform at a given temperature because of the action of diffusion, convection, and wind. Wind sets the surface water in motion and causes it to mix with water below. The stronger the wind, the faster the mixing proceeds and the greater the depth to which it extends.

Two physiological processes, respiration and photosynthesis, carried on by plants and other living organisms, often cause great variations in the oxygen content of the water. Mosses, algae, and other plants, besides the vines, grow in the bogs. Besides, bacteria and other micro-organisms exist in organic matter on the surface of bog soils and in the soil itself.

Respiration releases chemical energy mainly by the oxidation of carbohydrates. The energy is used for the performance of the physiological processes necessary to maintain life and goes on in every living cell. The process requires oxygen, and carbon dioxide is given off.

The oxygen used in respiration by the cranberry vines and other plants on a flooded bog is taken from that in solution in the water and the oxygen given off in photosynthesis goes into solution in it. Consequently, respiration reduces the amount of dissolved oxygen and photosynthesis increases it.

The oxygen content of water on winter-flooded bogs not covered with ice usually undergoes only relatively small, brief changes, as there is nearly always enough wind to cause mixing, so that the water is kept at or near its oxygen capacity.

On winter-flooded bogs covered by ice, circulation of the water by wind is prevented. The oxygen content of the water is then determined by the relative rate of oxygen consumption by the cranberry vines and the other organisms, as compared with the rate of liberation of oxygen in photosynthesis, mainly in the cranberry vines themselves. Since respiration goes on continuously, while photosynthesis occurs only in light, the oxygen content of the water increases or decreases at a rate proportional to the amount by which the oxygen given off in photosynthesis is greater or less than that used in respiration. Light, therefore, becomes the controlling factor in determining the oxygen content of the water on an ice-covered bog.

The amount of light received by the cranberry vines in water under ice depends primarily on the degree and duration of cloudiness, the thickness of the ice, the inclusion of snow in the ice, and the presence or absence of a snow cover.

Snow on the ice is the most important factor in causing a reduction in the oxygen content of water on winter-flooded bogs, since by excluding light, it prevents the liberation of oxygen in photosynthesis. The inclusion of snow in the ice may sometimes cause almost as great a reduction in the oxygen content of the water under ice as does snow on the ice.

The amount of oxygen required by vines frozen into the ice probably becomes negligible at the low temperature of ice in cold weather. It is always less than that required by vines in water under the ice. That may be an important factor in determining the probability of injury from oxygen deficiency and in determining the severity of injury when an oxygen deficiency occurs. Numerous observations have shown that shallowly flooded vines, which are frozen into the ice during the winter, produce larger crops and bear more regularly than those deeply flooded.

Different parts of the plant vary greatly in their oxygen requirement. The more active the part, the more oxygen it requires. The most active parts of cranberry vines in their winter condition are the flower buds, young leaves, and the growing point of the stem within the terminal buds. They are the first to be injured or killed, therefore, when the oxygen content of the water reaches a low level. The old leaves are much less active. The stems are least active and accordingly are injured only under extreme conditions of oxygen deficiency.

Injury occurs only when the oxygen content of the water reaches a level at which the oxygen requirement of the more active parts of the cranberry vines cannot be supplied. Evidence indicates that this level is about 5.7 parts per million, since injury occurs when the oxygen content of the water reaches that level and remains there for a day or two. The injury is more severe at a lower oxygen content or for a greater length of time. Usually the oxygen content of the water falls to that level only when there are several inches of snow on the ice, but it may do so in very cloudy weather when there is little or no snow on the ice, but much snow is included in it.

Injury from oxygen deficiency on winter-flooded bogs may be greatly reduced or prevented by changes in the flooding practice. Bogs are often flooded too deeply or for too long a time. Bogs should be flooded for as short a time as weather permits and should be flooded as shallowly as possible. Shallowly flooded vines are soon frozen into the ice when ice forms and then are injured less. On bogs that are much out of grade, some parts must be deeply flooded if the higher parts are covered. Then it usually would be better (in Massachusetts and New Jersey) to flood the bog shallowly and run the risk of some winterkilling on the higher parts. Moreover, the loss in yield as a result of oxygen deficiency injury to vines in water under ice on deeply flooded parts of a bog in most years and on most bogs is much greater than the loss from winterkilling on parts of the bog not flooded.

When the water supply is ample, bogs may be flooded in the usual way. Then after 5 to 6 inches of ice have formed, if the oxygen content of the water drops to near 5.7 parts per million, the water should be drawn out from under the ice. As long as ice remains, the bog need not be reflooded, but as soon as the ice melts from any considerable part of the bog it should again be flooded. This procedure has been used with success in Wisconsin and has been used on many bogs in Massachusetts when winters were cold enough to make ice of the desired thickness.

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Problems in Growing Pecans

John R. Cole

Several fungus diseases affect pecans. One of them, scab, is considered one of the major obstacles in pecan production and causes losses of millions of dollars to the industry annually.

The scab fungus was first found on leaves of the mocker hickory nut near Cobden, Ill., in 1882. Six years later it was found on leaves of the pecan near St. Martinsville, La. At that time growing of pecans was confined mostly to native trees in Illinois, Indiana, Tennessee, Texas, Louisiana, Oklahoma, Arkansas, and Mississippi. The first orchards were planted in Louisiana and Mississippi about 1880. By 1900 several large orchards had been planted in Georgia and Florida and orchard plantings had increased in the Southwestern States. Now the industry is extensive in the Southeast as well as the Southwest.

On the leaves, shoots, and nuts of susceptible varieties, the fungus causes premature defoliation and mummified nuts. Severely infected nuts may drop prematurely or they may die and remain attached to the shoots for an indefinite period. The scab disease is perpetuated from the old lesions. Because growing tissue only is susceptible, both foliage and nuts become immune to scab at maturity.

Pecan scab has been reported in every State where the crop is grown, but the disease causes most damage in localities where rainfall is frequent and high humidity prevails.